



# **A COTS RF/Optical Software Defined Radio for the Integrated Radio and Optical Communications Test Bed**

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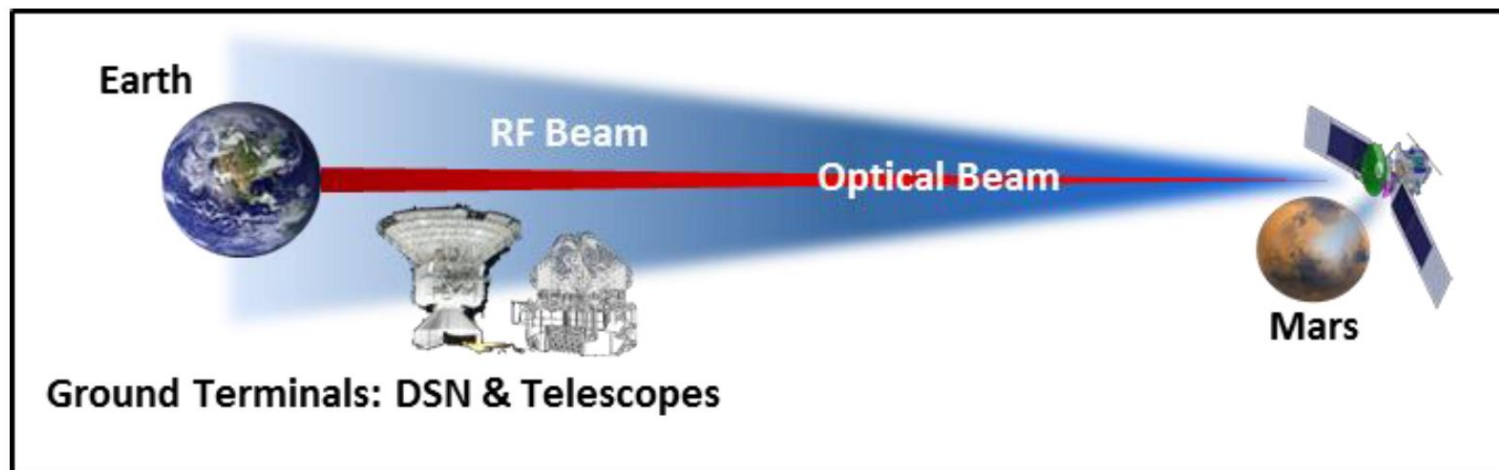


RF/Optical Transmitter  
and Optical Receiver

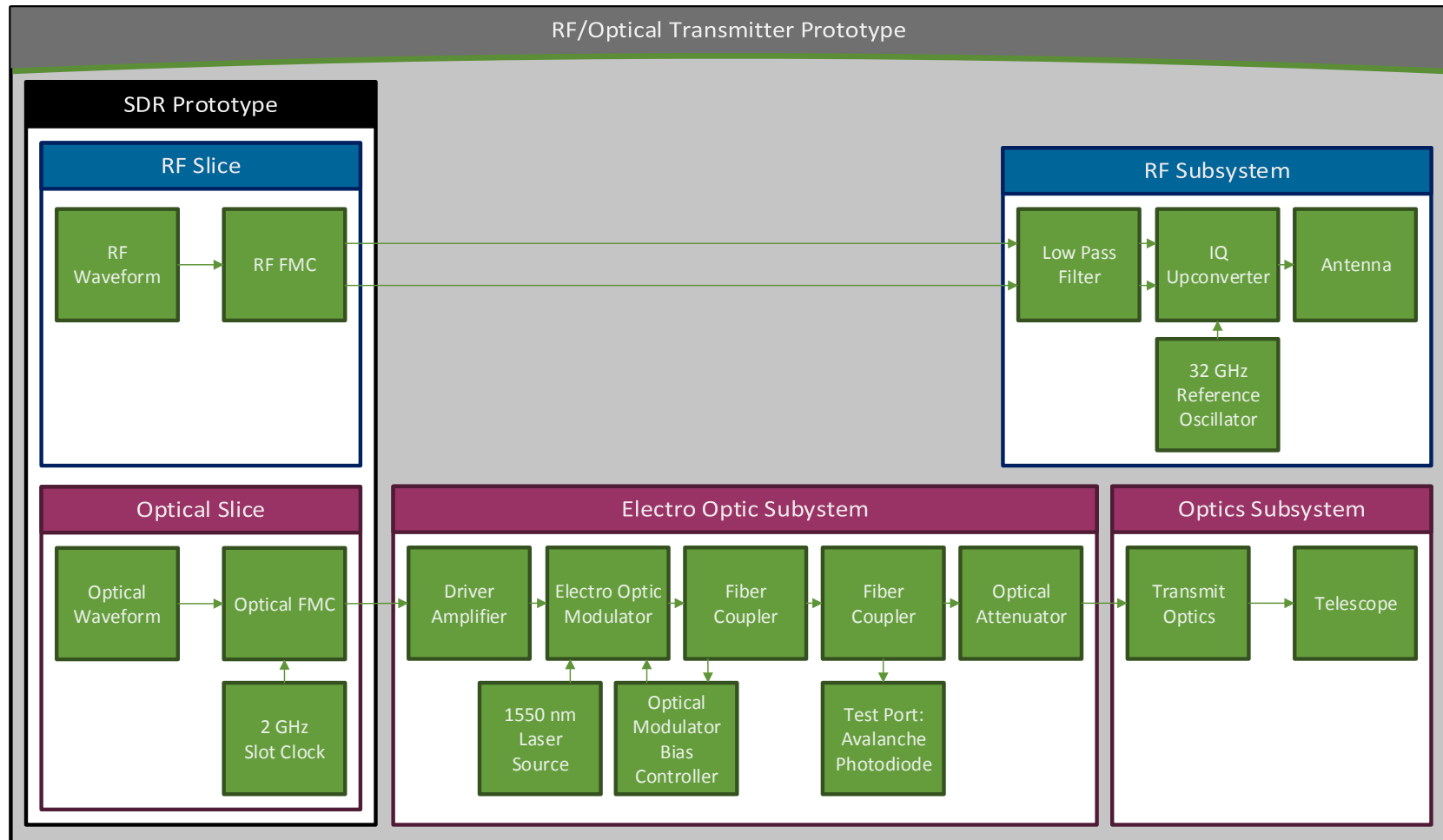
# Integrated Radio and Optical Communications Project (iROC) Overview

## Description:

- Technology development program for integration of RF and optical deep space communication systems.
- Key areas of development include:
  - RF antenna + optical telescope = teletenna
  - Beaconless (open loop) optical pointing
  - RF/Optical software defined radio

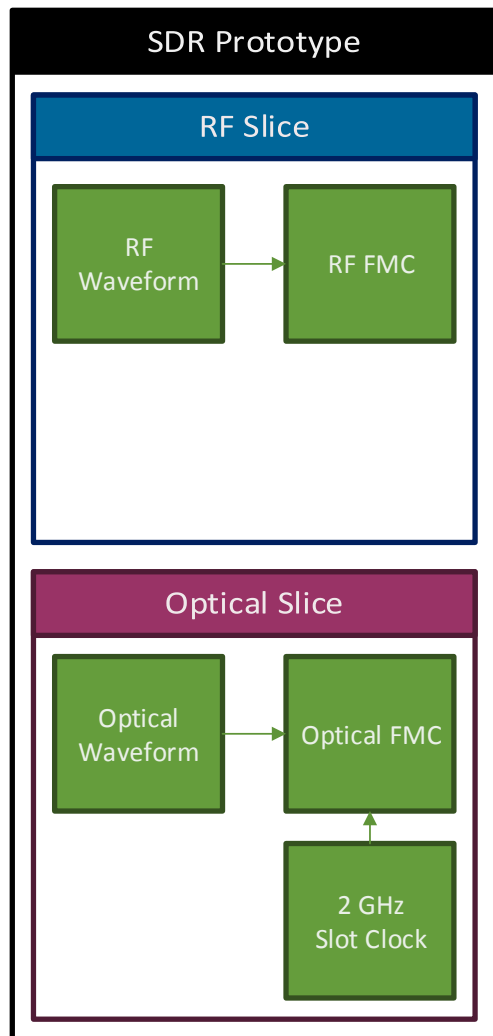


# Transmitter Architecture Overview



The transmitter includes: Software Defined Radio (SDR) Prototype, the RF Subsystem, The Electro Optic Subsystem, and the Optics Subsystem

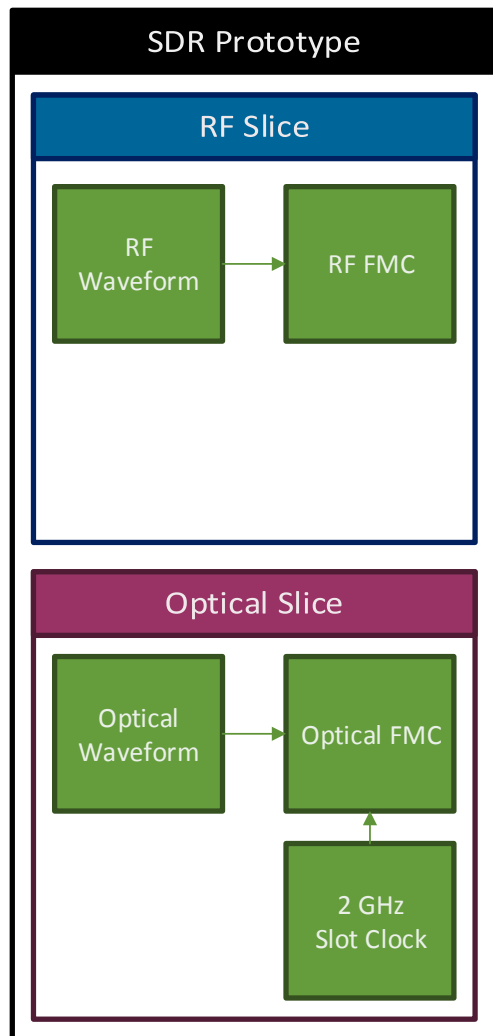
# Software Defined Radio Prototype



RF and Optical waveforms are integrated onto one Xilinx field programmable gate array (FPGA) development board.

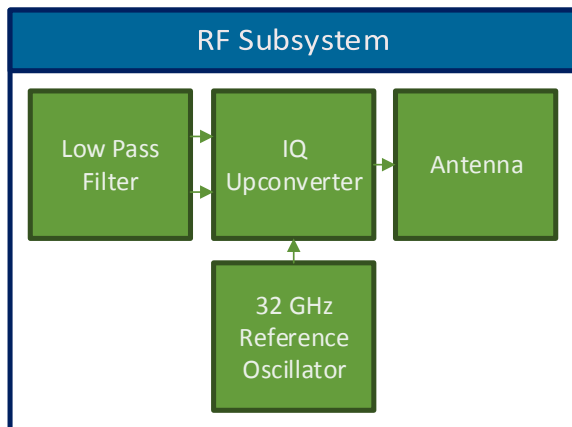


# RF Slice



- RF Waveform: Offset quadrature phase shift keying (QPSK)
- Symbol rate: 46.08 MSps
- RF FPGA Mezzanine Card (FMC): Contains a digital to analog converter (DAC) and oscillator at 737.28 MHz which is used to drive the RF waveform.

# RF Subsystem



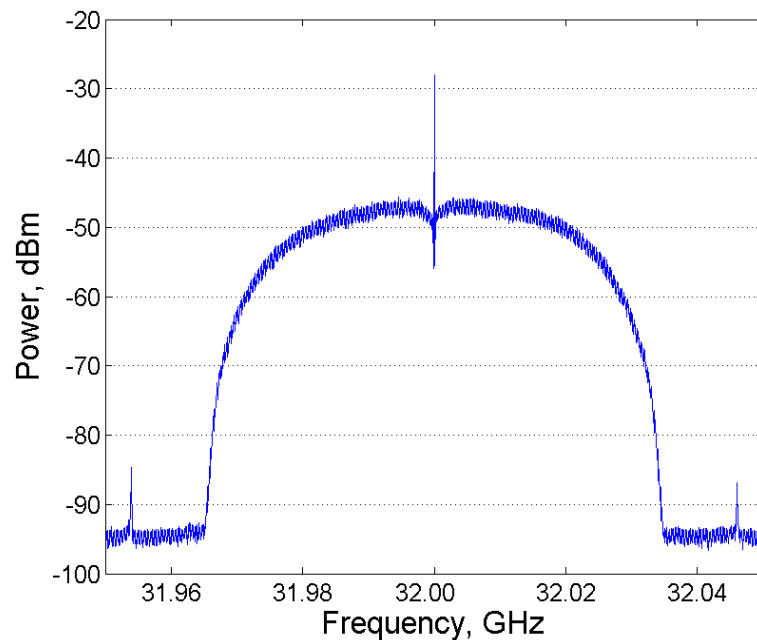
The RF subsystem interfaces to the DAC from the SDR, filters, mixes, and upconverts the I/Q signals from baseband to RF.

## Components

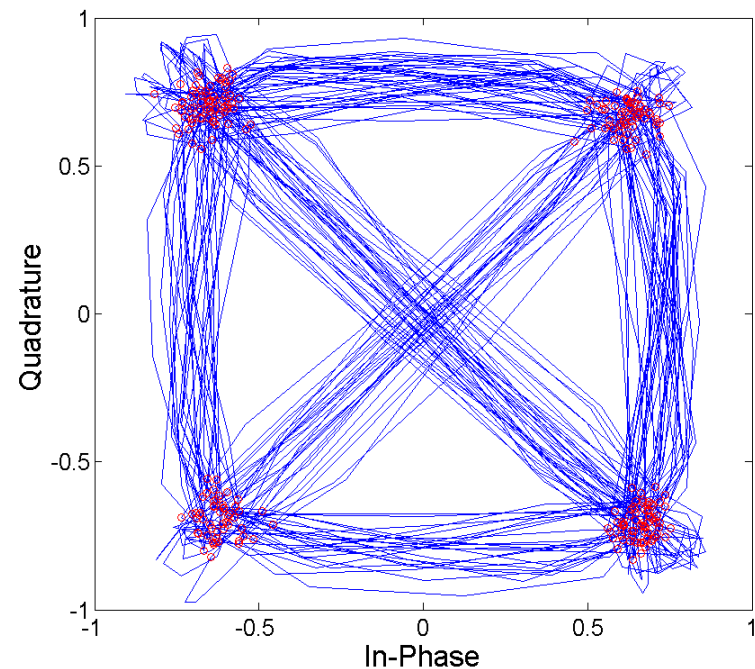
- Low pass filter
- I/Q upconverter
- 32 GHz reference oscillator

# RF Testing Results

## Transmit Signal Spectrum



## Constellation Diagram

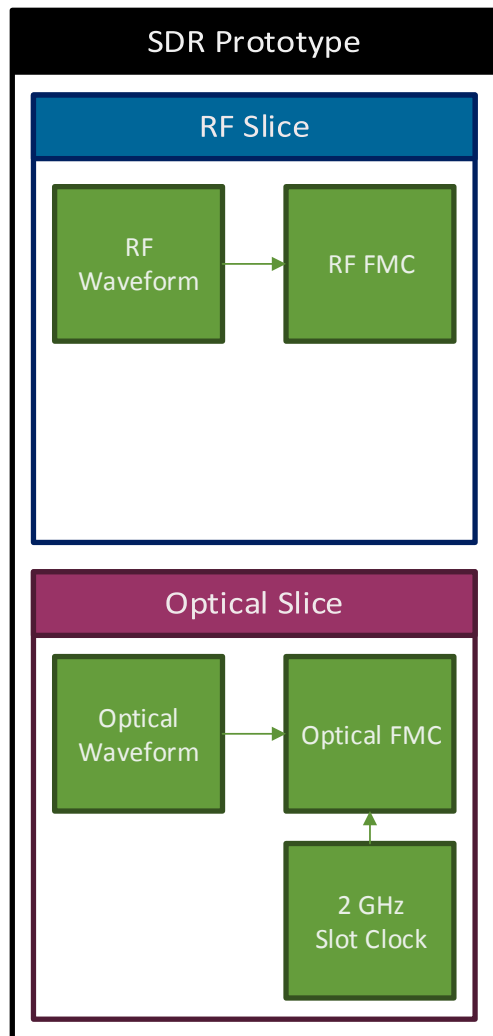


Description	Value	Units
Error Vector Magnitude	11.105	%rms
Phase Error	6.520	Deg



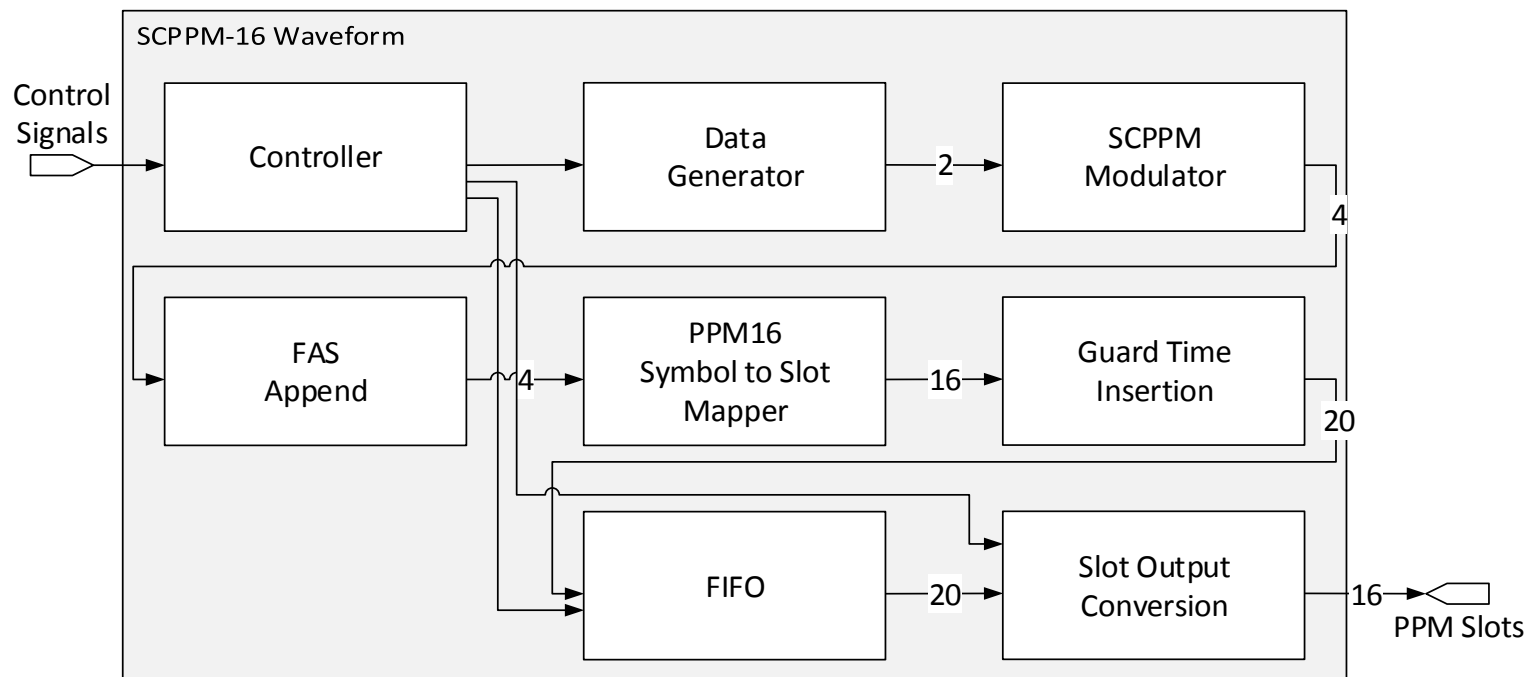


# Optical Slice



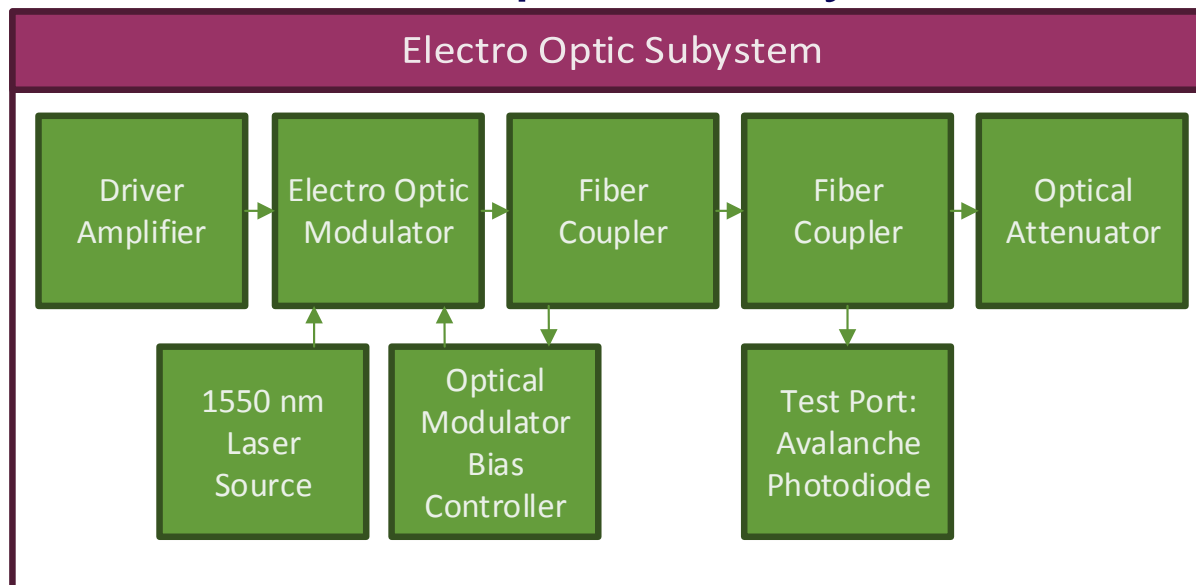
- Optical Waveform: SCPPM-16 (serially concatenated pulse position modulation), rate  $\frac{1}{2}$  code
- Data rate: 200 Mbps
- Optical FPGA Mezzanine Card (FMC): Performs 16 to 1 parallel to serial conversion and divides the 2 GHz (0.5 ns) slot clock by 16 to drive the waveform.

# Optical SCPPM Waveform



- SCPPM-16 (serially concatenated pulse position modulation), rate  $\frac{1}{2}$  code
- 4 slots inter symbol guard time
- 16 symbol frame acquisition sequence between code words

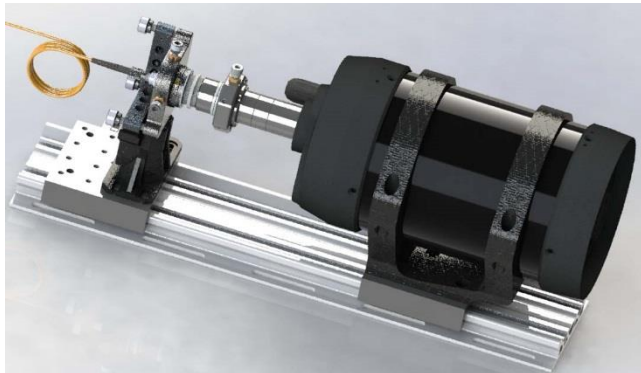
# Electro Optic Subsystem



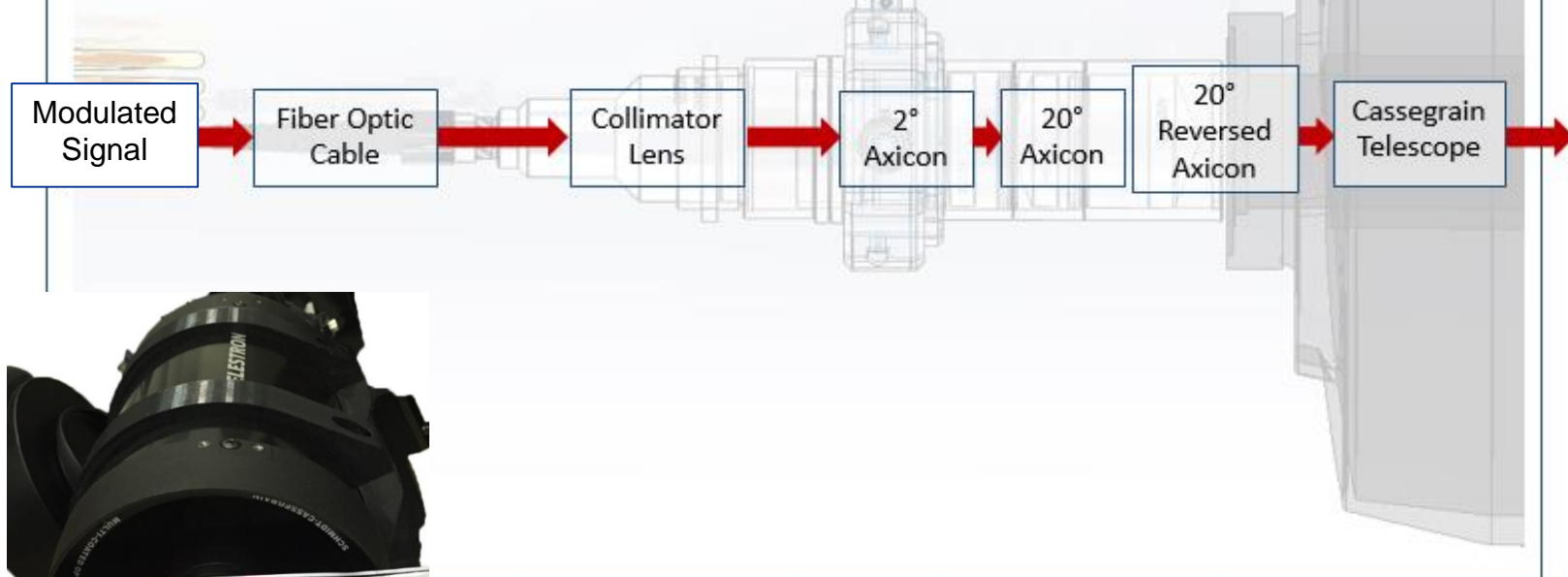
## Components

- Driver amplifier
- Lithium niobate electro optic modulator
  - 20 dB extinction ratio
  - >40 dB extinction ratio
- Bias controller
- 1550 nm laser source
- Optical attenuator

# Optics Subsystem



Transmitter



A series of axicon lenses maximizes the transmitted power by directing nearly all of the laser power around the secondary reflector.



# Optical Testing Results

Specified Electro Optic Modulator Extinction Ratio	Code Words Processed	Code Word Errors	$K_s$ (photons/signal slot)	$K_b$ (photons/slot)	Average PMT Current ( $\mu\text{A}$ )
20 dB	43,900	14	3.6	0.037	0.91
>40 dB	43,900	4	4.3	0.0025	0.93

## Configuration:

- Modulation: SCPPM-16, rate  $\frac{1}{2}$
- Slot clock: 20 MHz (50 ns)
- Data rate: 2 Mbps
- Receiver post processing system



# Conclusions

- RF and Optical COTS prototype was designed and tested in a laboratory
- Future work includes porting the design to a platform designed for space



# Acknowledgements

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- This work was performed under the NASA SCaN Program at the NASA Glenn Research Center.